Indian J. Phys. **52A**, 401–404 (1978)

Radiative decays of vector mesons in a chiral SU(4)×SU(4) breaking scheme

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(*Received* 21 *September* 1977, *revised* 17 *October* 1977)

The radiative decays of vector mesons are studied in a broken $SU(4) \times SU(4)$ scheme. Results obtained for the decay widths are comparable with the experimental data.

1. Introduction

Recent measurements of the radiative decay widths of several vector mesons have made the study of the $VP\gamma$ vertex very important. Several authors (O'Donnell 1977, Edwards & Kamal 1976, Boal, Graham & Moffat 1976) have investigated the symmetry and symmetry breaking structure of such a vertex in various schemes. While Boal, Graham and Moffat (1976) obtained good predictions of the new rates in a nonet breaking scheme with a vector mixing angle of 24°, Edwards & Kamal (1976) attempted to obtain quantitative fits to the experimental data by introducing $SU(3)$ breaking in the effective $VP\gamma$ vertex. A modification of the hadronic vertex was also carried out by Thews (1976) who introduced mass dependent exponential form factors at the hadronic vertex. In a recent paper, Nandy, Bagchi and Ray (1978) emphasized the necessity of considering suppression due to off shell effects at both the hadronic and photonic vertices. However, an alternative mechanism for reduced $V \rightarrow P\gamma$ decays was proposed by Mitra (1976) to account for the considerably reduced widths in $V \rightarrow P\gamma$ decays via the recoil effect under the quark pair creation hypothesis. Some time back Bajaj & Khanna (1977) studied the consequences of introducing a small admixture of a singlet piece in the electromagnetic current.

To include the radiative decays of ψ, Edwards & Kamal (1976) suggested the possibility of extending their $SU(3)$ breaking schemes to $SU(4)$. An analog of the *ABCD model* was discussed by them and several conclusions were drawn from its structure. In this paper, we consider an $SU(4) \times SU(4)$ generalization of the current algebra model as developed by Edwards & Kamal (1976) in the spirit of Aubrecht & Razmi (1975) and discuss some of the consequences.

In section 2 we present the theory and the results are discussed in section 3.

2. Theory

The symmetry breaking Hamiltonian can be taken as

$$H = \alpha u_0 + \beta u_8 + \gamma u_{15}$$

where α, β and γ are parameters; u_i together with v_i ($i = 0, 1, \ldots, 15$) form a pair of 16-plet of scalar and pseudoscalar densities belonging to the $(4, \bar{4})+(\bar{4}, 4)$ representation of chiral $SU(4)\times SU(4)$.

Using current algebra techniques, the symmetry breaking structure of the strong $VP\gamma$ vertex is developed in the following manner

The axial vector currents have the divergences

$$\partial_\mu A_i^\mu(x) = f_i m_i^2 P_i(x)$$

where f is the decay constant of the pseudoscalar meson P.

By taking soft meson limits, one can write

$$< V^n P^i \mid H(0) \mid V^l > \propto \frac{1}{f} (\alpha d_{0ik} + \beta d_{8ik} + \gamma d_{15ik}) < V^n \mid A_0^k(0) \mid V^l >,$$
$$i, l, n, k = 0, \ldots, 15 \qquad \ldots \quad (1)$$

Assuming

$$< V^n \mid A_0^k(0) \mid V^l > = h d_{nkl} \qquad \ldots \quad (2)$$

one can use VDM to write

$$\Gamma(V^j \to P^i\gamma) = \left(\frac{M_j^2 - M_i^2}{2M} \right)^3 \frac{1}{f_i^2} (c_0 d_{jin} + c_8 d_{8ik} d_{kjn} + c_{15} d_{15ik} d_{kjn})^2 \qquad \ldots \quad (3)$$

where $i, j, k = 0, \ldots, 15$, $n = (3) + \frac{1}{\sqrt{3}}(8) - \sqrt{\frac{2}{3}}(15) + \frac{\sqrt{2}}{3}(0)$ following Glashow Iliopoulos & Maiani (1970), and c_0, c_8, c_{15} are parameters to be determined.

The mixing of the basis states $|8>$, $|15>$ and $|0>$ to form three physical isoscalar mesons can be described (Boal & Torgerson 1977) in terms of three Euler angles ϵ, δ and θ where the rotation matrix U is given by

$$U = \begin{bmatrix} \cos\epsilon \sin\theta + \sin\epsilon \cos\delta \cos\theta & -\sin\epsilon \sin\theta + \cos\epsilon \cos\delta \cos\theta & \sin\delta \cos\theta \\ -\cos\epsilon \cos\theta + \sin\epsilon \cos\delta \sin\theta & \sin\epsilon \cos\theta + \cos\epsilon \cos\delta \sin\theta & \sin\delta \sin\theta \\ -\sin\epsilon \sin\delta & -\cos\epsilon \sin\delta & \cos\delta \end{bmatrix} \qquad \ldots \quad (4)$$

Thus,

$$\begin{bmatrix} \omega \\ \phi \\ \psi \end{bmatrix} = U \begin{bmatrix} 8 \\ 15 \\ 0 \end{bmatrix} \quad \text{and} \quad \begin{bmatrix} \eta' \\ \eta \\ \eta_c \end{bmatrix} = U \begin{bmatrix} 8 \\ 15 \\ 0 \end{bmatrix} \qquad \ldots (5)$$

and the ideal mixing is given by

$$\epsilon = 0^\circ,\ \delta = 60^\circ \text{ and } \theta = \tan^{-1}(\sqrt{\tfrac{1}{2}}). \qquad \ldots (6)$$

3. Results and Discussion

In our approach all $V \to P\gamma$ decay widths have been expressed (eq 3) in terms of three parameters viz., c_0, c_8 and c_{15} which get fixed up by any three widths as input if decay constants are known. The input widths have been underlined in Table 1 The results obtained by us are shown in Table 1. All the decay constants are taken equal in solutions 1 and 2 However, a fit $f_k = 1{\cdot}26 f_\pi = {\cdot}395 f_\eta = {\cdot}338 f_\eta'$ and f_{η_c} = average $(f_\pi, f_k, f_\eta, f_\eta')$ is assumed in solution 3.

$$\frac{\Gamma(\omega \to \pi\gamma)}{\Gamma(\rho^- \to \pi^-\gamma)} \approx 9{\cdot}2 \quad \text{and} \quad \frac{\Gamma(K^{0*} \to K^0\gamma)}{\Gamma(K^{+*} \to K^+\gamma)} \simeq 4$$

become fixed from current algebra considerations; so are the ratios*

$$\frac{\Gamma(\omega \to \pi\gamma)}{\Gamma(\psi \to \pi\gamma)} \quad \text{and} \quad \frac{\Gamma(\omega \to \pi\gamma)}{\Gamma(\phi \to \pi\gamma)}$$

Thus, whenever $\Gamma(\omega \to \pi\gamma)$ is taken as input $\Gamma(\rho^- \to \pi^-\gamma)$, $\Gamma(\phi \to \pi\gamma)$ and $\Gamma(\psi \to \pi\gamma)$ become automatically fixed.

The ratio $\dfrac{\Gamma(\psi \to \eta'\gamma)}{\Gamma(\psi \to \eta\gamma)}$ is taken to be 1·5 in solution 1 and 2·1 in solution 2 as inputs. The main effect of this change seems to be on $\eta_c \to \omega\gamma$ decay. Otherwise, both the solutions fit all the data except $\phi \to \eta\gamma$, $\phi \to \pi\gamma$ nand $\rho^- \to \pi^-\gamma$

In solution 3 we have taken a fit mentioned before because f_η, f_η' and f_{η_c} are not known experimentally. $\Gamma(\omega \to \pi\gamma)$ as input makes it impossible to adjust $\Gamma(\phi \to \pi\gamma)$ and $\Gamma(\rho^- \to \pi^-\gamma)$. $\Gamma(\phi \to \pi\gamma)$ and $\Gamma(\rho^- \to \pi^-\gamma)$ apart, solution 3 fits all the available data.

Acknowledgement

B.B. thanks Dr. A Nandy for helpful discussions and the Council of Scientific and Industrial Research, New Delhi for financial support.

* $\psi \to \pi\gamma$ and $\phi \to \pi\gamma$ are completely forbidden for an exact ideal mixing given in (6). The vector mixing angles are taken ($\theta = 35^\circ$, $\delta = 59{\cdot}8^\circ$ and $\epsilon = 0^\circ$) slightly different from the ideal mixing. The pseudoscalar mixing angles are taken from Boal and Torgerson (1976).

Table 1

Decay Widths	Solution 1	Solution 2	Solution 3	Expt
$\rho^- \to \pi^- \gamma$	91·6 KeV	91·6 KeV	91·7 KeV	35 ± 10 KeV[+]
$K^{0*} \to K^0 \gamma$	74·9 ,,	74·9 ,,	74 ,,	75 ± 35 ,,[+]
$\omega \to \pi\gamma$	843·9 ,,	843·8 ,,	845·0 ,,	880 ± 61 ,,[+]
$\phi \to \eta\gamma$	710·5 ,,	710·0 ,,	91·4 ,,	82 ± 17 ,,[+]
$\rho \to \eta\gamma$	61·8 ,,	61·8 ,,	6·1 ,,	—
$K^{*+} \to K^+ \gamma$	19·0 ,,	19·0 ,,	18·8 ,,	< 80 ,,[+]
$\omega \to \eta\gamma$	22·5 ,,	22·5 ,,	2·6 ,,	< 50 ,,[+]
$\phi \to \eta'\gamma$	4·1 ,,	4·1 ,,	0·39 ,,	—
$\psi \to \eta\gamma$	105·3 eV	97·7 eV	44·3 eV	55 ± 12 eV[++]
$\psi \to \eta'\gamma$	157·5 eV	201·9 eV	155·0 eV	152 ± 117 eV[++]
$(\psi \to \eta'\gamma)/(\psi \to \eta\gamma)$	1·5	2·1	4·1	1·8 ± ·8[+++]
$(\eta' \to \rho\gamma)/(\eta' \to \omega\gamma)$	16·2	16·2	10·7	10 ± 5[+]
$\psi \to \eta\ \gamma$	22·7 KeV	23·1 KeV	16·7 KeV	< 1 KeV[++++]
$\eta_c \to \rho\gamma$	27·6 eV	27·5 eV	4·9 eV	—
$\eta_c \to \omega\gamma$	0·3 eV	0·0034 eV	5·9 eV	—
$\eta_c \to \phi\gamma$	10·7 KeV	11·1 KeV	2·7 KeV	—
$\psi \to \pi\gamma$	$6·3 \times 10^{-3}$ eV	$6·3 \times 10^{-3}$ eV	$6·4 \times 10^{-3}$ eV	5 ± 3·2 eV[++]
$\phi \to \pi\gamma$	0·93 eV	0·93 eV	0·93 eV	5·9 ± 2·1 KeV[+]

[+] P. J. O'Donnell (1977)
[++] W. Braunschweig *et al* (1977)
[+++] W. Bartel *et al* (1977)
[++++] Boral & Torgerson (1977)

References

Aubrecht II G. J. & Razmi M. S. K. 1975 *Phys. Rev.* **D13**, 2120.
Bartel W. 1977 *Phys. Lett.* **66B**, 488
Bajaj J. & Khanna M. P. 1977 *Pramana* **8**, 309
Boal D. H., Graham R. H. & Moffat J. W. 1976 *Phys. Rev. Lett.* **39**, 714.
Boral D. H. & Torgerson R. 1977 *Phys. Rev.* **D15**, 327
Braunschweig *et al* 1977 *Phys. Lett.* **67B**, 243
Edwards B. J. & Kamal A. N. 1976 *Ann. Phys.* (N.Y.) **102**, 252.
Glashow S. L., Iliopoulos J. & Maiani L. 1970 *Phys. Rev.* **D2**, 1285.
Mitra A. N. 1976 *Phys. Rev.* **D14**, 835.
Nandy A., Bagchi B. & Ray S. 1978 J. Phys. **G 4**, 989.
O'Donnell P. J. 1977 *Can. J. Phys.* **55**, 1301.
Thews R. L. 1976 *Phys. Rev.* **D14**, 3021.